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Relationship Between Image Size and Tone Reproduction Curve

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RELATIONSHIP BETWEEN IMAGE SIZE AND TONE REPRODUCTION CURVE

by

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and

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ABSTRACT

This project attempts to find a relationship between preferred tone reproduction and image size.

Photographic prints with different tone reproduction characteristics were made. The differences were very small but just noticeable. Prints were made in three different sizes and compared to a standard size print by a paired comparison method. Analysis showed that there was no tone reproduction difference in the preferred prints of both smaller and larger sizes.

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SECTION ONE

Introduction

The photographic and graphic arts industry are both dealing with the reproduction of images. This may be the reproduction of an original scene to a photograph, an original photograph to a second generation reproduction or, finally, a reproduction of a reproduction. In any one of these cases there is a possibility of a change in image size from the original to the reproduction. At this point there is a question as to whether the tone reproduction parameters in the original should match those of a reproduction of a different size.

There are several factors that must be considered when reproducing a scene. These factors include the visual adaptation of the eye as well as other subjective judgements of graininess, sharpness, and resolving power. The evaluation of any process involving the human visual system can be complicated by the fact that what the eye sees is not necessarily what the brain perceives. One such complication is the phenonomen of simultaneous contrast which refers to the brightness of the surround and its effect on the appearance of an object. A gray patch appears lighter when surrounded by a dark area than it does when surrounded with a light area. This effect varies with the angular subtense at the eye of the areas involved so that it might not be visible in a large area outdoors but would be very apparent if the scene were reduced to an eight by ten print. The phenonomen of successive contrast occurs when the eye fixates on different areas of a scene. The previous fixation has an effect on the adaptation of the eye for the next fixation. This occurs throughout the viewing of an object.

In the volumes of literature on objective and subjective tone reproduction there has not yet been a rigorous study of the effect that the size of a reflection print has upon the visual adaptation of the eye and how this relates to the objective parameters of a photographic print. As image size decreases there is an apparent reduction in perceived image sharpness and edge contrast. It can also be expected that some of the mechanisms of visual perception will also change with image size. The question that occurs at this point is what objective parameters in a print must be changed to make a print of one size look like a print of a significantly larger or smaller size.

It ~~is~~ was the intent of this research project to use the photographic machines and processes available to create objective differences in print quality and size, and to determine the effect that different image sizes have on subjective judgements of the prints.

SECTION TWO

A. Tone Reproduction Curve Variation

B. Photographic Printing Method

C. Subjective Evaluation

The purpose of this research project can best be described by the following question: When reproducing a black and white photograph, in a different size, how must the tone reproduction curve be changed to obtain optimum similarity?

A. Tone Reproduction Curve Variation

In a similar study done by Miller, the Hell Chromograph C286 color scanner at the Graphic Arts Research Center was used to produce the tone reproduction variations necessary for the experiment. The scanner system is essentially a microdensitometer which reads an image that is placed on a spinning drum. The signal from the image is then passed through a computer section where it can be modified for color correction, gradation, and other parameters useful in the graphic arts. The signal is then converted to a light beam which exposes a piece of film that is rotating in synchronization with the original. By using the gradation controls alone a black and white negative can be modified to any number of tone reproduction curves.

The negative used was a low contrast portrait on a 2 and 1/4 inch square format. The reproductions obtained are shown in Figure I.

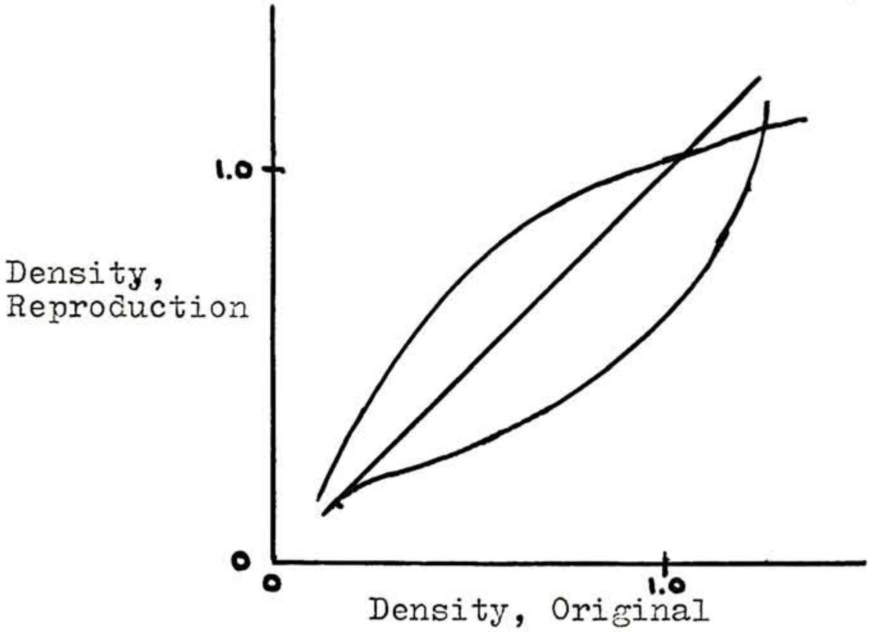


Figure I

The effect of these distortions in the final print tone reproduction can be seen in Figure 2. The curve with increasing gradient printed with a substantial loss in shadow detail when compared to the original. All three curves have a great difference in the printed density of a middle-flesh tone. This results when all three reproductions are printed to constant endpoint densities. Printing to a constant flesh tone density was similarly investigated, but the differences in the resulting curves was not great enough to allow for a valid conclusion at the end of the experiment.

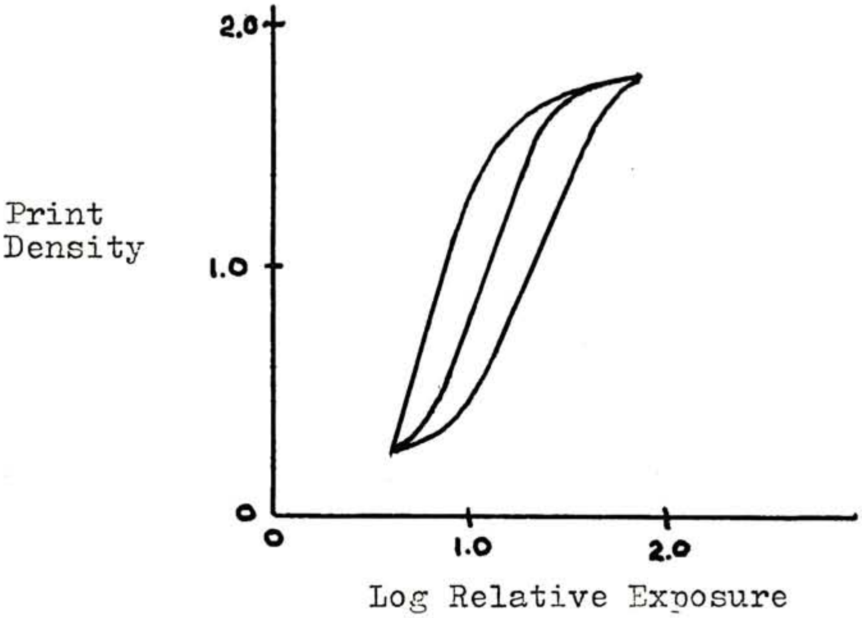


Figure2

Since direct utilization of the scanner by the authors was not possible, and since there was a considerable time delay involved in producing the reproductions, this course of investigation was abandoned. In order to devise a correlation between image size and tone reproduction curve, it ~~will~~ was be necessary to produce prints that differ in tone reproduction and size but not to the extent where the differences in reproduction are so great that they cannot effectiely be judged. The production of such prints by using the photographic printing process alone was then investigated.

B. Photographic Printing Method

In order to produce prints of different tone reproduction characteristics the parameters by which the prints will be compared must first be defined. Exposure, as measured by the printed reflection density of a middle-flesh tone was one such parameter. The author's experience has shown that a twenty percent difference in density is just visually detectable. The other parameter, contrast, was defined as the difference in the printed reflection densities between the highlight and shadow areas. A five percent difference in contrast was considered just detectable.

A step wedge was added to the negative and used as a guide to measuring exposure and contrast. The steps used were those that most closely matched those of the previously mentioned areas in the negative.

A variable contrast printing paper was used. The color correction filters in the enlarger provided the filtration for different contrasts. As a starting point a print was produced that, in the experimenters' opinion, would be the best print possible for that particular negative. The exposure and contrast for this print was measured and from this a three level square matrix was created by increasing and decreasing both exposure and contrast by their previously defined levels. Duplicate matrices were produced in the smaller and larger sizes.

The size of the original print was 15.9 cm square. The larger and smaller prints were 23.2 cm and 9.1 cm square respectively. These differences in magnification were selected due to their suitability in fitting the equipment and paper sizes available.

Although much care was taken to eliminate variability in the processing procedures it was found to be very difficult to obtain any kind of repeatability in the printing process. Combinations of exposure time and magenta or yellow filtration were tried until the desired densities were obtained. Limited time and lack of repeatability can be blamed for any inconsistencies between levels and between sizes.

C. <u>Subjective Evaluation</u>

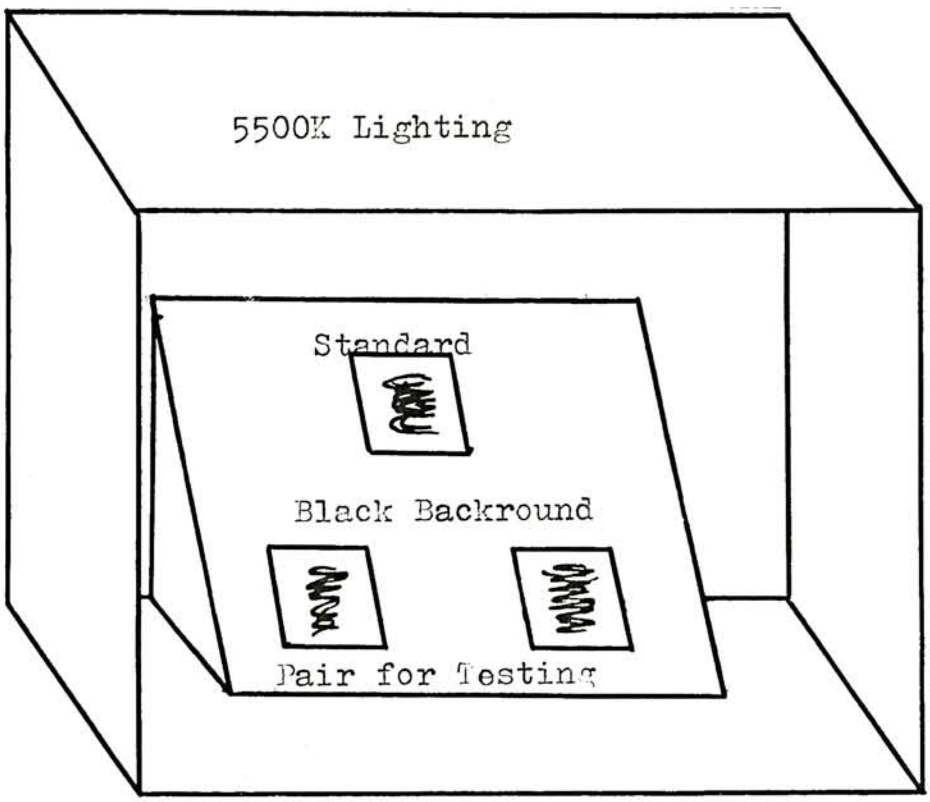
The finished matricies were then judged by a group of viewers. The prints were mounted on a black surround and placed in a large MacBeth viewing booth with 5500°K lighting. The inner surfaces of the booth were covered with gray paper. A large gray cardboard was used for displaying the prints. The basic display format is shown in the following diagrams.

Most of the viewers were senior photo science students. They were given the following instructions for judging the prints:

TONE REPRODUCTION

You will be shown three prints. Of the three two will be in a pair and the third will be separated from the other two. From the pair, tell me which one looks most like the third.

Viewing Conditions



The test consisted of a paired comparison where the observer was asked to pick which ~~of~~ of a pair of prints looked most like a standard print which was never taken from the observer's view. The order of presentation and results are found in Appendix D. The time for a single test was 10-15 minutes and consisted of one observer comparing the nine prints of one size matrix in all possible pairs. The standard print was a duplicate of the center of the standard size matrix. There were a total of five observers for each size matrix. Some observers were used to judge other size matricies but the same five observers were not used for all sizes.

Most observers commented that during the course of the test their criteria for judging the prints changed, especially when two prints were very close in tone reproduction.

SECTION THREE

Analysis and Results

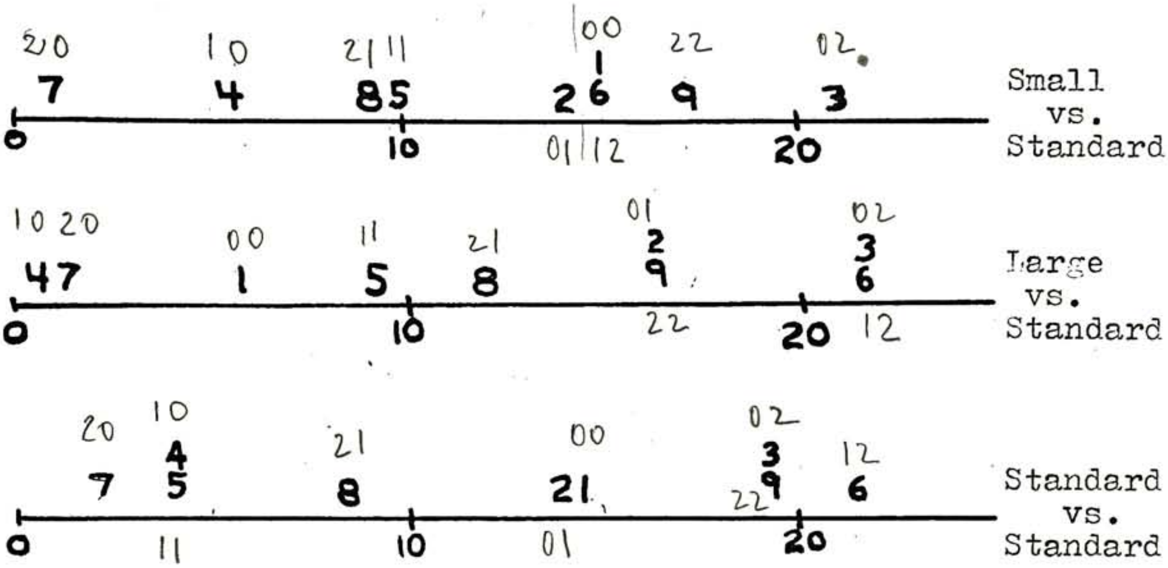
The paired comparison test used was picked for several reasons. First of all, it is necessary to make the test brief, as observer fatigue and boredom can significantly effect results. Also, the observer was left with a simple left-right choice, making the mathmatical calculations very simple. This type of test also allows the observer to be evaluated as to his consistency in judgement. This is done by calculating triads. A triad is formed when the observer says print A is better than print B; print B better than C; and C better than A. It is possible to detect such inconsistencies and to eliminate data where inconsistencies are numerous.

The prints were numbered according to the following diagram:

Exposure

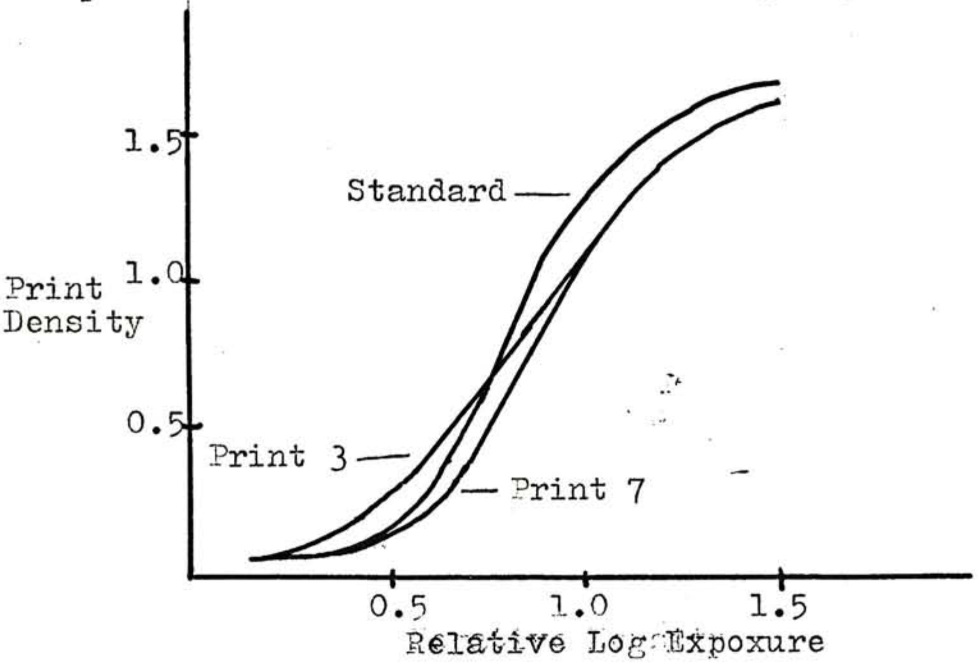
		-20%	0	+20%
	-5%	1	2	3
Contrast	0	4	5	6
	+5%	7	8	9

The mathematical analysis of the results provides us with a ranking of nine prints on an interval scale for each size matrix. In all cases two viewers' data were eliminated due to numerous false triads. There are now a total of three observers for each size matrix.

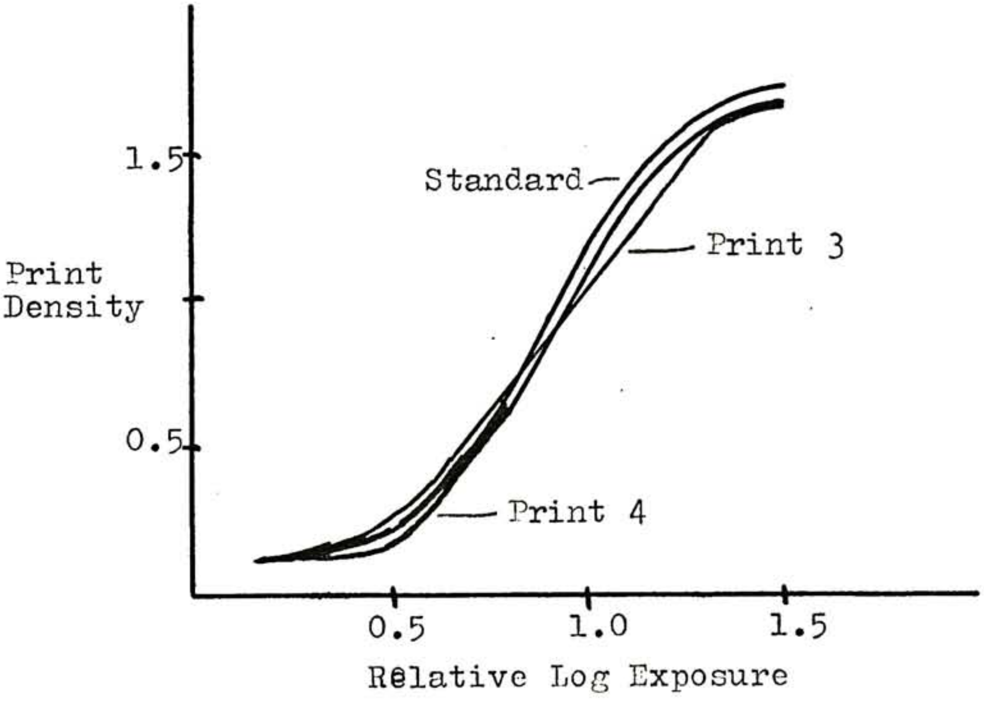


In all cases print 7 was ranked highly along with print 4, even when prints of the same size were being compared. Prints 4 and 7 are on the low exposure-high contrast side of the matrix. In view of the test used and in consideration of the observers comments, our results would seem to indicate that when a viewer was presented with two prints that were very close in tone reproduction he tended to pick the lighter print even if the darker one was identical to the standard. This could be a consequence of the presentation conditions. It was not possible to change the left-right format of the test as outlined in Appendix D, but care was taken to not allow the observer to discover our method of comparison.

The prints on the high exposure side were consistently ranked low. This emphasizes the point that in a forced choice situation our observers always picked the lighter print. It can be assumed that when two very close prints were compared the observer disregarded the comparison to the standard and picked the lighter print as a preference over the darker one. The portrait used was of such a nature that when exposure was increased facial blemishes became more noticeable and the shoulder outline became more defined. In the standard the shoulder outline just blended in with the backround. This could be the criteria by which the darker prints were downgraded. The objective tone reproduction curves of the prints in question are shown in the following figures.



Small Size Comparison



Large Size Comparison

SECTION FOUR

Conclusion

Our results quite clearly show that our viewers did not desire any change in tone reproduction when looking at a smaller or larger print. The observers consistently picked the low exposure prints as a best match, although their ability to distinguish small differences must be questioned as they could not pick the identical print from the standard size matrix. This could very well be a result of our viewing conditions or type of test. Also the number of viewers was small for a conclusive determination in this type of test.

Further work in this area should include subjective evaluation with a greater number of observers. Our method of producing prints and measures of determining exposure and contrast seem to be quite suitable for producing prints with the desired small increments. Additional testing should also include images of different characteristics. The nature of our portrait could alone be a cause of our results.

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APPENDIX A

The original negative was exposed with a $2\frac{1}{4}$ by $2\frac{1}{4}$ format camera by a professional photography student. The portrait was done with standard studio lighting and Eastman Kodak film type Plus-X pan was used.

Processing:

The film was processed in a 16 oz. tank in the following manner:

Developer-	D-76 1:1
Temperature-	68F
Time-	8 min.

Standard tank agitation was used.

This was followed by a 30 sec. stop bath and a 10 min. fix.

APPENDIX B

Tone reproduction curve variations were produced with a Hell Chromograph C286 color scanner located in the Graphic Arts Research Center. Due to the complexity in the operation of the scanner and its availability the negative was reproduced for us in a few weeks. Because the negative was a medium size format it was scanned at 1000 lines per inch.

APPENDIX C

Reflection prints were made from the scanner reproduced negatives with a projection and a 75mm lens. The lens was also equipped with a 1.5 inch extension tube to facilitate the making of the necessary size images.

Paper: Eastman Kodak Portralure, Surface G, double weight.

Printer: Chromega Dichroic Enlarger equipped with a solid state timer.

Safelight: One Eastman Kodak type OC with a 35 watt bulb at a distance of at least 15 feet.

Processing:

Developer-	D-72 1:2
Temperature-	68F
Time-	1 min.

Tray agitation.

It must be pointed out that the developer was replaced when the equivalent of five 8 X 10 inch prints were processed to reduce process variability.

This was followed by:

Stop bath-	28% Acetic Acid, 1:32, 30 sec.
Fixer-	10 min.
Running water wash-	5 min.
Hypo Clearing agent-	3 min.
Running water wash-	10 min.

The excess water was removed with a squeegee. The prints were then dried on a Pako Commercial Print drier.

Reflection prints for final testing were made directly from the original negative by projection printing as previously described with the following changes:

Paper: Eastman Kodak type Polycontrast, Surface G, double weight.

Processing:

Time-	1.5 min.

Three different size prints were made with nine Tone Reproduction variations as follows:

Image size	A = 9.1 X 9.1 cm
	B = 15.9 X 15.9 cm
	C = 23.2 X 23.2 cm
Contrast levels	L = normal -5%
	N = normal
	H = normal +5%
Exposure levels	L = normal -20%
	N = normal
	H = normal +20%

The following is a table of the prints produced:

SIZE	CONTRAST/ EXPOSURE	FILTRATION	EXPOSURE TIME	APERTURE f/#
B	L/L	15Y	3.2 sec.	11
	N/L	15Y	3.8	11
	H/L	15Y	4.2	11
	L/N	65M	3.6	11
	N/N	65M	4.0	11
	H/N	65M	4.4	11
	L/H	105M	3.8	11
	N/H	105M	4.4	11
	H/H	125M	4.8	11
A	L/L	15Y	3.6	16
	N/L	15Y	3.8	16
	H/L	15Y	4.4	16
	L/N	65M	3.8	16
	N/N	65M	4.2	16
	H/N	65M	4.6	16
	L/H	105M	4.6	16
	H/H	125M	5.0	16
C	L/L	25M	6.2	11
	N/L	15Y	6.8	11
	H/L	15Y	7.4	11
	L/N	65M	7.2	11
	N/N	65M	8.8	11
	H/N	65M	9.4	11
	L/H	65M	7.6	11
	N/H	105M	8.4	11
	H/H	65M	9.4	11

APPENDIX D

Presentation of Prints

Prints were presented two at a time in the following order. L and R indicate the observers left and right side. This table shows all possible combinations of nine prints. The observer did not know that the print on the left side was not being changed each time a pair was presented. Also included in the table is the results for one viewer.

L	vs. R	Observer
1	2	1
1	3	0
1	4	1
1	5	1
1	6	0
1	7	1
1	8	1
1	9	0
2	3	0
2	4	1
2	5	0
2	6	0
2	7	1
2	8	1
2	9	0
3	4	1
3	5	1
3	6	1
3	7	1
3	8	1
3	9	0

L	vs. R	Observer
4	5	0
4	6	0
4	7	1
4	8	0
4	9	0
5	6	0
5	7	1
5	8	1
5	9	0
6	7	1
6	8	1
6	9	0
7	8	0
7	9	0
8	9	0

APPENDIX E

Statistical Analysis

The data from appendix D is rearranged to form the upper triangular part of a matrix. The lower triangular part is filled in with the row value minus 1 and the absolute value is recorded ($|\text{row value} - 1|$). The row totals are then found and the expected value for each row is subtracted from it and the result is squared. The expected value for each row is the total of the row totals divided by nine. This infers that all the rows should have equal values and therefore be the same. This is consistent with the null hypothesis. H_0: There is no difference between rows.

	Print #											
	1	2	3	4	5	6	7	8	9	Row Total	Expected Value	$(T-E)^2$
1	-	1	0	1	1	0	1	1	0	5	4	1
2	0	-	0	1	0	0	1	1	0	3	4	1
3	1	1	-	1	1	1	1	1	0	7	4	9
4	0	0	0	-	0	0	1	0	0	1	4	9
5	0	1	0	1	-	0	1	1	0	4	4	0
6	1	1	0	1	1	-	1	1	0	6	4	4
7	0	0	0	0	0	0	-	0	0	0	4	16
8	0	0	0	1	0	0	1	-	0	2	4	4
9	1	1	1	1	1	1	1	1	-	8	4	16
												60

The calculation for triads for this observer is as follows:

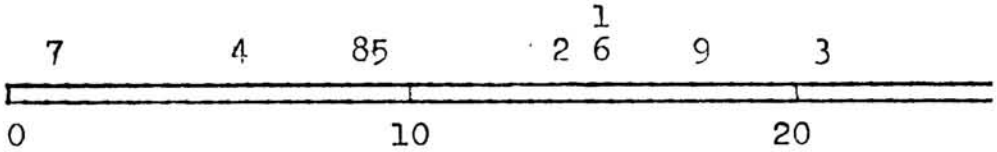
$$T_{max} = (n^3 - n)/12 = (9^3 - 9)/12 = 720/12 = 60$$

$$\text{Triads} = (T_{max} - T)/2 = (60 - 60)/2 = 0$$

After each observer's data has been analyzed the row totals for each print are summed. These sums can now be plotted on a ranking interval scale. The results for this particular observer would look as follows:

7	4	8	2	5	1	6	3	9	Print#
0	1	2	3	4	5	6	7	8	Ranking

The conclusion from this scale would read as: print 7 was picked most times as being the closest match to the standard; print 4 was next best; and so on. It is noted that this observer displayed no triads therefore his results turn out to be ranking nine prints 0 - 8, which is most desirable. However, this is not the case when the data from all observers is summed. A typical scale for the small prints compared to the standard would look as follows:



APPENDIX E (cont'd)

The conclusion from this interval scale is: print 7 most like the standard and ranked higher than the rest. However, print 4 is also very close and being only two units apart it is difficult to tell if they are significantly different. It can be safely said that prints 4 and 7 match better than say 5, 6, or 3.

APPENDIX F

Exposure and Contrast Measurements

		EXPOSURE		
SIZE	CONTRAST	L	N	H
	L	0.20 LL 0.82	0.27 NL 1.03	0.32 HL 1.12
B	N	0.20 LN 0.96	0.26 NN 1.12	0.33 HN 1.23
	H	0.20 LH 1.02	0.26 NH 1.22	0.32 HH 1.23
	L	0.22 LL 0.82	0.28 NL 0.90	0.36 HL 1.04
A	N	0.22 LN 0.98	0.30 NN 1.16	0.34 HN 1.14
	H	0.24 LH 1.04	0.26 NH 1.12	0.34 HH 1.20
	L	0.22 LL 0.98	0.29 NL 0.96	0.33 HL 1.05
C	N	0.21 LN 1.10	0.28 NN 1.15	0.34 HN 1.28
	H	0.23 LN 1.12	0.28 NH 1.22	0.33 HH 1.29

Upper value: Exposure

Lower value: Contrast

Size A: 8.08cm x 8.08cm

Size B: 16.15cm x 16.15cm

Size C: 32.26cm x 32.26cm